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GPS/GNASS COMPATIBLE ANTENNAS

by

Zhang Fenglin

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ABSTRACT This article introduces a type of GPS/GLONASS compatible receiving antenna. It is an improvement on a four arm fractional type screw antenna. It opts for the use of such technologies as self-phased as well as open slot coaxial line top feed, and so on, in order to make antenna structure compact and volumes small. Introducing sleeve type reflectors, the symmetrical properties of antenna directional diagrams were very, very greatly improved, lowering rear lobe power levels. In conjunction with this, use is made of designs associated with transmission line theory on self-phased antennas to carry out theoretical analysis. Formulas were deduced for self-phased antenna designs. Test measurement results clearly show that, within GPS/GLONASS operating frequencies, the stationary wave ratio < 1.2 . The axial direction gain is approximately 4.2dB. When angles of elevation are over 10°, gains are ≥ -2dBi.

KEY TERMS GPS receiving antenna, GLONASS receiving antenna, Dome shaped directional diagram

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I. FORWARD

GPS and GLONASS are, respectively, global navigation and positioning systems set up by the U.S. and the former Soviet Union. No matter whether it is military uses or civilian applications, they grow broader by the day. Global positioning systems are divided into the two types of high dynamic and low dynamic. Antennas used in high dynamics require simultaneous reception of approximately 5 satellite signals or more. Antennas used in low dynamics require reception of signals from approximately 3 satellites. That is also to say that, when high dynamic antenna system angles of elevation are above 10°, gains should be ≥ -2dBi. However, when low dynamic system antenna angles of elevation are above 10°, the gains need only be ≥ - 5dBi. The former is primarily utilized with relatively high precision military uses. The latter is used in ordinary civilian situations.

We developed multiple types of global positioning system antennas--planar spiral antennas [1], micro belt antennas, and four arm fractional type spiral antennas. The results clearly show that, although micro belt antenna costs are low and volumes are very small, direction diagrams, however, are not adequately wide. They are only capable of use in low dynamic civilian situations. Moreover, frequency band widths are very narrow, and they cannot act as compatible antennas.

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* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

Outside of China, many types of GPS or GLONASS receiving antennas have already been developed. However, GPS/GLONASS compatible antennas have still not been reported. The newest GPS antenna indices currently received from outside China are set out in the table below.

Comparison of Partial U.S. GPS Antennas and the Antenna in Question

公司 (1)	型号 (2)	频率 (MHz) (3)	增益 (仰角 10°) (4)	驻波比 (5)	日期 (6)
Sensor systems Inc.	S67-1575-2	1575±10	-2dBi	1.5	1990
MAGELLAN Systems Corporation	X2-2	1575.42	-4.4dBi	1.6	1993.3
Tecom Industries, Inc.	401208	1575.42±10.23	-2.5dBi	2.0	1990
	401186	1575.42±10.23	-2dBi	1.75	1990
本天线 (7)	YW2-5	1550~1620	-2dBi	1.2	1992

Key: (1) Company (2) Model (3) Frequency (4) Gain (Angle of Elevation 10°) (5) Stationary Wave Ratio (6) Date

Primary indices of GPS/GLONASS compatible antennas:

Operating Frequency: 1575.42±1MHz (GPS)

1609±8MHz (GLONASS)

Direction Diagram: Dome Shaped Hemisphere

Gain: ≥ -2dBi (angle of elevation 10° or over)

Polarization: Right Handed Circular Polarization

Stationary Wave Ratio: 1.5:1 /18

II. SELF-PHASED FOUR ARM FRACTIONAL SPIRAL ANTENNA DESIGNS (CALLED SIMPLY VOLUTE)

Standard Volute antennas [2] belong to a class of spiral type feed line four arm antenna. They are also a type of special spiral antenna. They are made up of two sets of orthogonal spirals as shown in Fig.1. The phases of the four basic spiral feed lines are 0°, 90°, 180°, and 270°. The electrical design of this type of antenna is simple. Debugging is easy. However, the structure is complicated and the volume is large. Moreover, there is a need for such electrical feed devices as 90° phase shifters, and so on. These are expensive. Here, we make use of principles similar to those of self-phased cross oscillator circular polarized antennas and develop a type of structure that is relatively simple. Volumes are small. Moreover, there is no need for "self-phased" volute antenna feed devices, as shown in Fig.2. The operational principles are as follows.

Taking the spiral resonance length as $lo = \lambda$, one pair of spiral lengths $l1 = lo + \lambda$. Its currents are relative to (-45°) phase shifts produced by resonance configurations. Another pair of spiral lengths $l2 = lo - \Delta$, making it produce (-45°) phase shifts as compared to resonance configurations, thus the current phase difference between long arms and short arms is 90°, realizing circular polarized radiation.

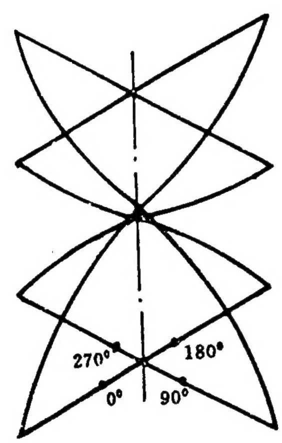

Fig.1 Resonance Type Four Arm Fractional Model Spiral Antenna

With regard to standard types of volute antenna, there are people who have used moment measurement methods to do theoretical analyses. However, there is still no one who has done analyses on "self phased" type antennas. Precise specifications of the regulation length Δ have no theoretical guidance. They can only be precisely determined from experiments. Speaking in terms of ordinary "self phased" cross oscillators, there are already large amounts of experimental data. Moreover, the experimental adjustments are already very convenient. They only require working a number of tuning screws, and that will do it. However, speaking in terms of the antennas in question, not only is there no experimental data. Moreover, it is very

clear that, due to the fact that the upper and lower ends of the spirals have already been welded, adjustment is very difficult. As a result, how analyses are gotten of the orders of magnitude of Δ theoretically has very great practical significance. Otherwise the amounts of experimental work very greatly surprise people.

To this end, we presented a theoretical model which is capable of giving long and short spiral length differences, that is, 2Δ, $l1 - l2 = 2\Delta$.

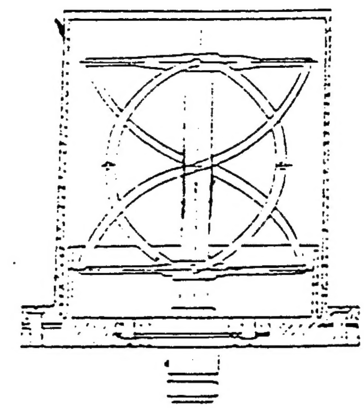

Fig.2 GPS/GLONASS Compatible Antenna (Corrected Type Self-Phased Spiral Antenna)

Take a pair of spirals AA' and BB' to be equivalent to a section of terminal circuit transmission line as shown in Fig.3.

From microwave transmission line theory, it is known that the currents on this line are :

$$I\,(l) = I_0\,(e^{-rl} + e^{-2rL} e^{rl})$$

L is arm length: L = AA'. r is a transmission coefficient. $r = \alpha + j\beta$. α is an attenuation constant. β is a transmission constant.

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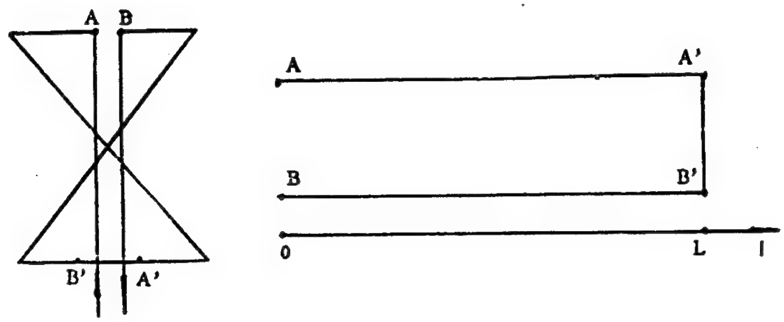

Fig.3 Microwave Transmission Line Equivalency Chart

The equation above can be changed to become

$$I(l) = I_0 \left(e^{-\alpha l} \cdot e^{-j\beta l} + e^{\alpha(l-2L)} e^{j\beta(l-2L)}\right)$$

When $L = lo + \Delta = \lambda + \Delta$, the equation above can be changed to become:

$$I(l) = I_0 \left(e^{-\alpha l} \cdot e^{-j\beta l} - e^{-\alpha(2L-l)} \cdot e^{j\beta l} \cdot e^{-j\frac{4\pi}{\lambda}\Delta}\right)$$

At feed line point (l=0):

$$I(0) = I_0 \ (1 + e^{-2\alpha L} cos(4\pi \frac{\Delta}{\lambda})$$
$$- je^{-2\alpha L} sin(4\pi \frac{\Delta}{\lambda})) \qquad (1)$$

When Δ=0, that is, spiral line currents are placed in resonance configurations,

I (0) = I. As far as (1+e-2al) is concerned, the imaginary part is 0. That is, during resonance, current phase is 0°.

In order to make long and short oscillators produce (±45°) phase difference, from equation (1), one knows that the equations below must be set up:

$$1 - e^{-2\alpha L} cos(4\pi \frac{\Delta}{\lambda}) =$$
$$\downarrow e^{-2\alpha L} sin(4\pi \frac{\Delta}{\lambda})$$

That is,

$$\text{即:} \cos(4\pi\frac{\triangle}{\lambda}) \Downarrow \sin(4\pi\frac{\triangle}{\lambda}) = -e^{2\alpha L} \tag{2}$$

Equation (2) is the circular polarity conditions produced by two pairs of orthogonal terminal circuit curve oscillators (oscillator lengths = $\lambda/2$, λ, ...). In the same way, it is possible to infer the remaining situations--for example, formulae directed toward when there are common crossed oscillators (terminal open circuits).

During design engineering, it is possible to take $\alpha \approx 0.5$. From equation (2), it is possible to obtain: $\Delta = 0.138\ \lambda$.

Therefore, $l1 = l0 + \Delta = 1.138\lambda$. $l2 = l. - \Delta = 0.862\lambda$.

Here, take λ=190mm. Δ = 26.3mm. l1=216.3mm. l2=163.7mm.

Considering increased thickness of long arms and thinning of short arms, it is then advantageous to opt for the use of relatively short l1. In actuality, long arm diameters are Φ2.5mm. Short arms are Φ1.5mm. Going through multiple iterations of debugging, precise determinations were made of l1=208 and l2=161. It is possible to obtain relatively good results.

However, due to direction diagrams being extremely wide, working precision are, in addition, difficult to guarantee. One has the appearance of direction diagrams which are not symmetrical, making a number of planar direction diagrams not wide enough and incapable of satisfying requirements. Moreover, rear lobes are large as

well as there being the production of such flaws as bad consistency.

III. IMPROVED MODELS OF SELF-PHASED TYPE VOLUTE ANTENNAS

In order to eliminate the shortcomings discussed above, a number of improvements were also carried out. On the foundation of Volute antennas described above and going through multiple iterations of tests, a sleeve type reflector was designed as shown in Fig.2. The dimensions are diameter Φ70mm, height 21mm. Going through test measurements, the flaws discussed above associated with unimproved antennas were overcome. Directional diagram symmetry characteristics were good. Rear lobes were low. The various indices were completely achieved. Moreover, working was consistently good.

The antenna that was finally settled on was as shown in Fig.2. Its characteristics are as follows:

(1) Opting for the use of "self-phased" type structures, there are savings on feed components, making volumes shrink;

(2) Opting for the use of top feed technology, structures are more compact and small than bottom feed situations (for example, as shown in Fig.1);

(3) The introduction of reflection sleeves very greatly improves antenna radiation characteristics. Moreover, volumes still do not increase very much.

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IV. TEST MEASUREMENT RESULTS AND CONCLUSIONS

As far as stationary wave ratio curves as shown in Fig.4 are concerned, it can be seen that, in the two GPS AND GLONASS frequency channels, stationary wave ratios VSWR < 12.

Directional diagrams and gain measurement results are shown in Fig.5. The gains are:

When $f = 1575$ MHz $G = 4.2$dBi (axial direction)

$G > -2$dBi (angle of elevation $\geq 10°$)

When $f = 1609$ MHz $G = 3.9$dBi (axial direction)

$G > -2$dBi (angle of elevation $\geq 10°$)

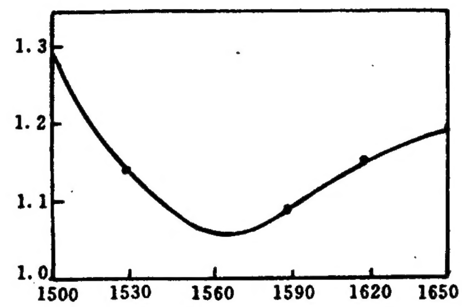

Fig.4 Compatible Antenna Measurement Stationary Wave Ratios

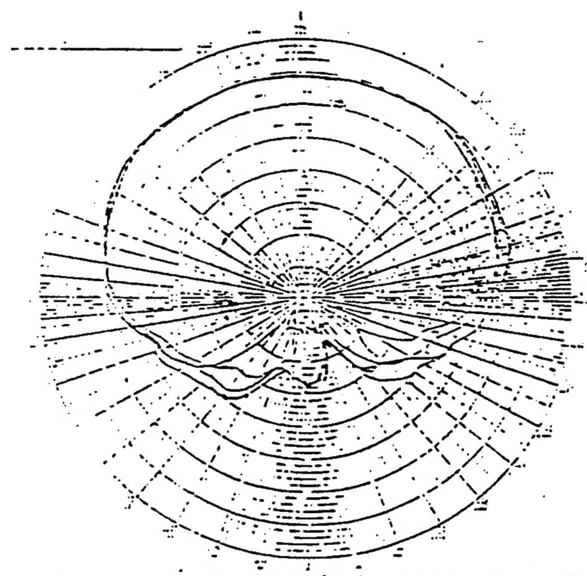

Fig.5a Compatible Antenna Four Cross Section Test Measurement Direction Diagram (GPS: fo = 1575 MHz)

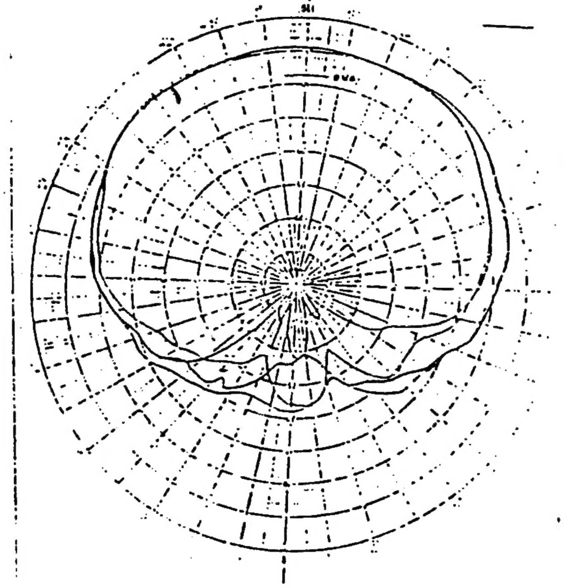

Fig.5b Compatible Antenna Four Cross Section Test Measurement Direction Diagram (GLONASS: fo = 1609 MHz)

CONCLUSIONS

This article introduced a type of corrected Volute antenna. In conjunction with that, use was made of transmission line theory to infer design formulae for self-phased antennas. From the test data discussed above, it can be seen that this antenna direction diagram is very broad. Moreover, it is symmetrical, and all the various indices reach GPS/GLONASS compatible antenna requirements.

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